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(54) INDIRECT FIRED HEAT EXCHANGER

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(52) **U.S. Cl.**

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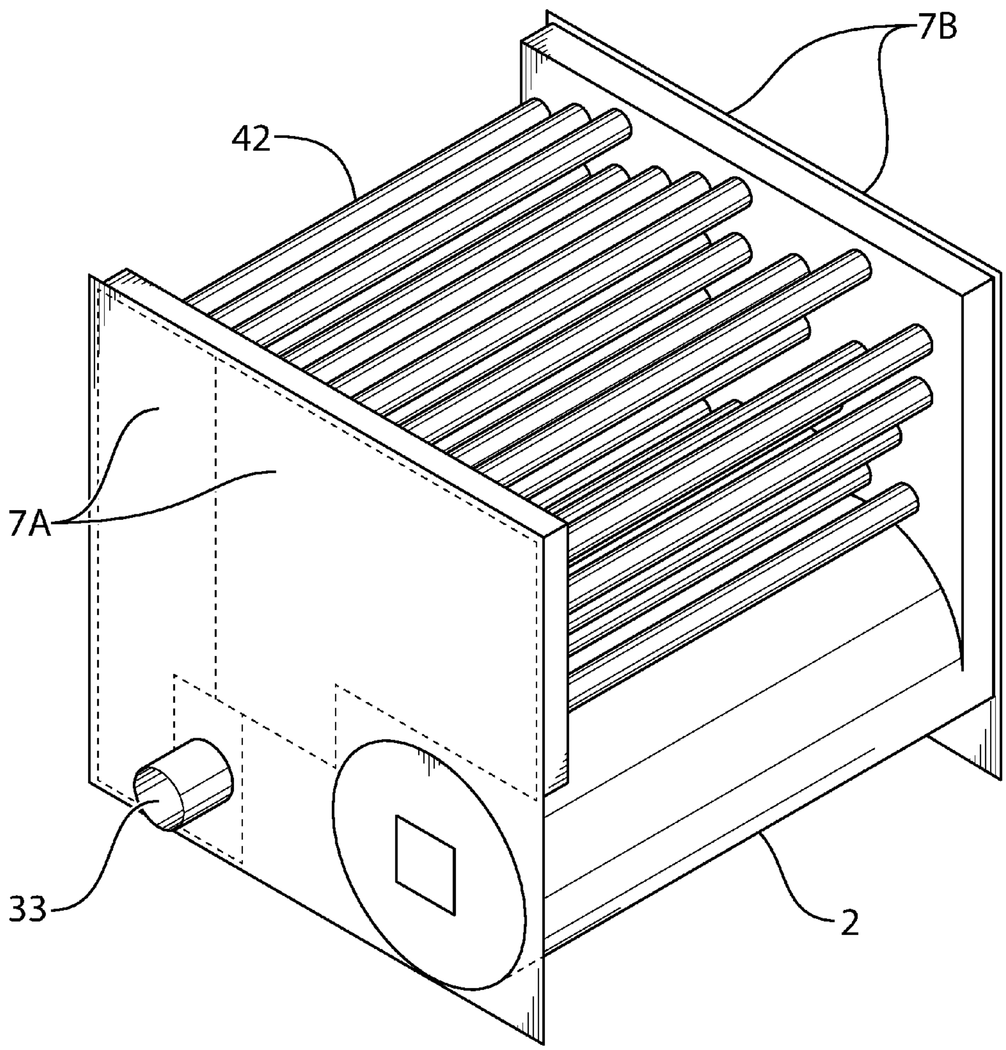
(57) **ABSTRACT**

An indirect fired heat exchanger is provided, comprising an arcuate airflow pattern.



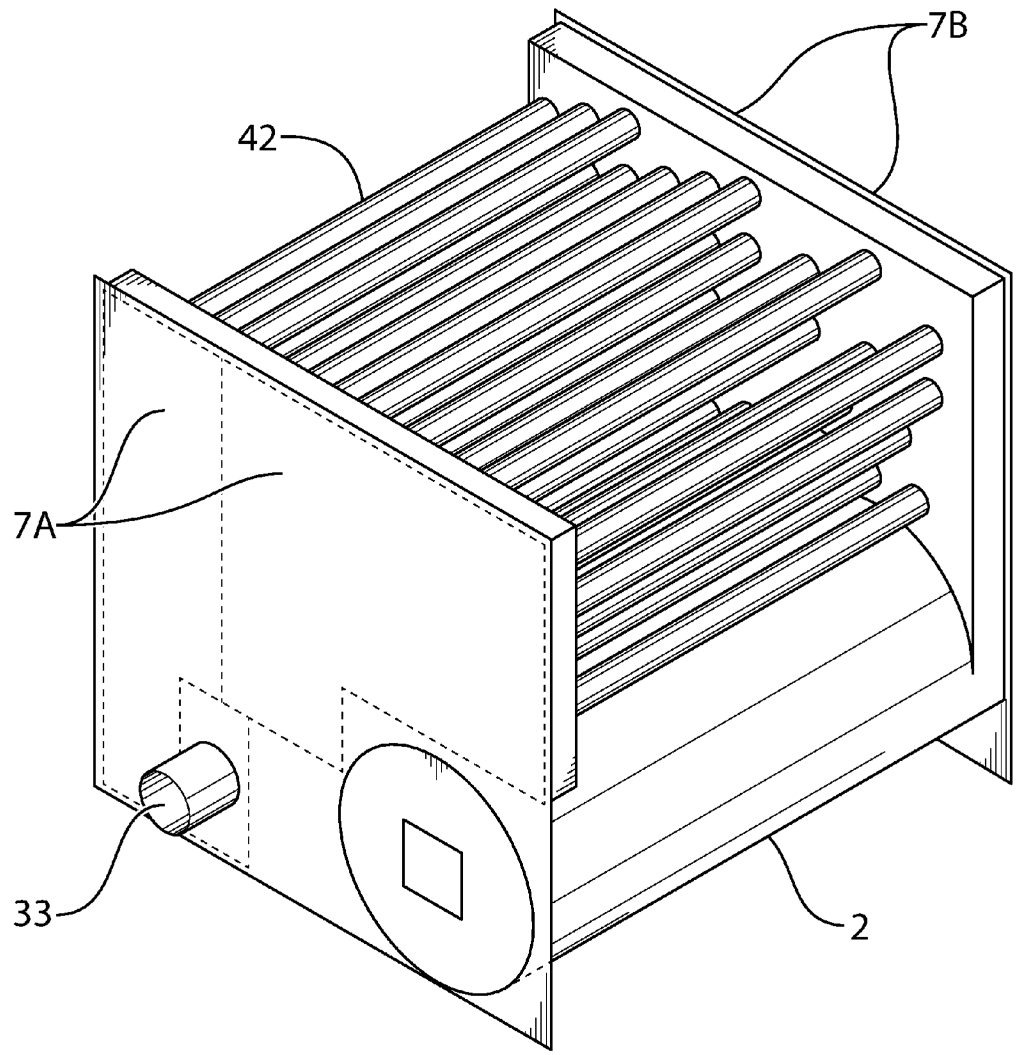


FIG. 1

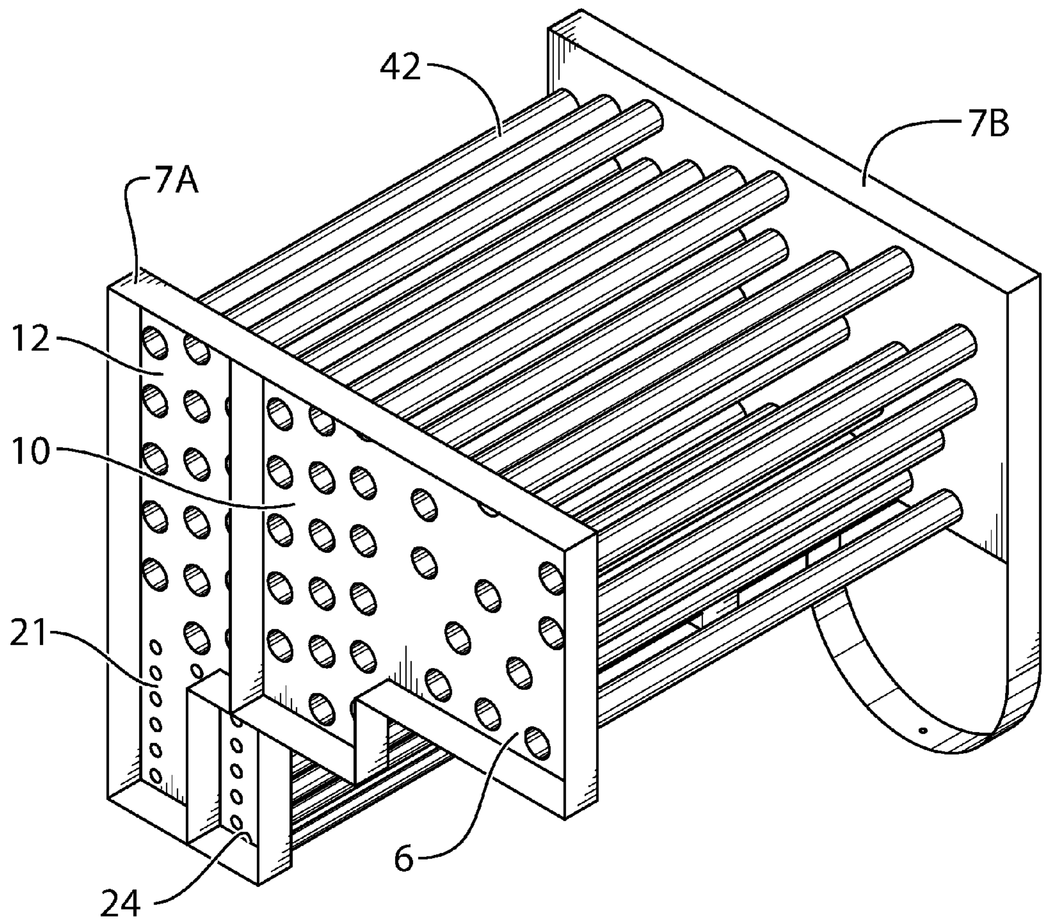


FIG. 2A

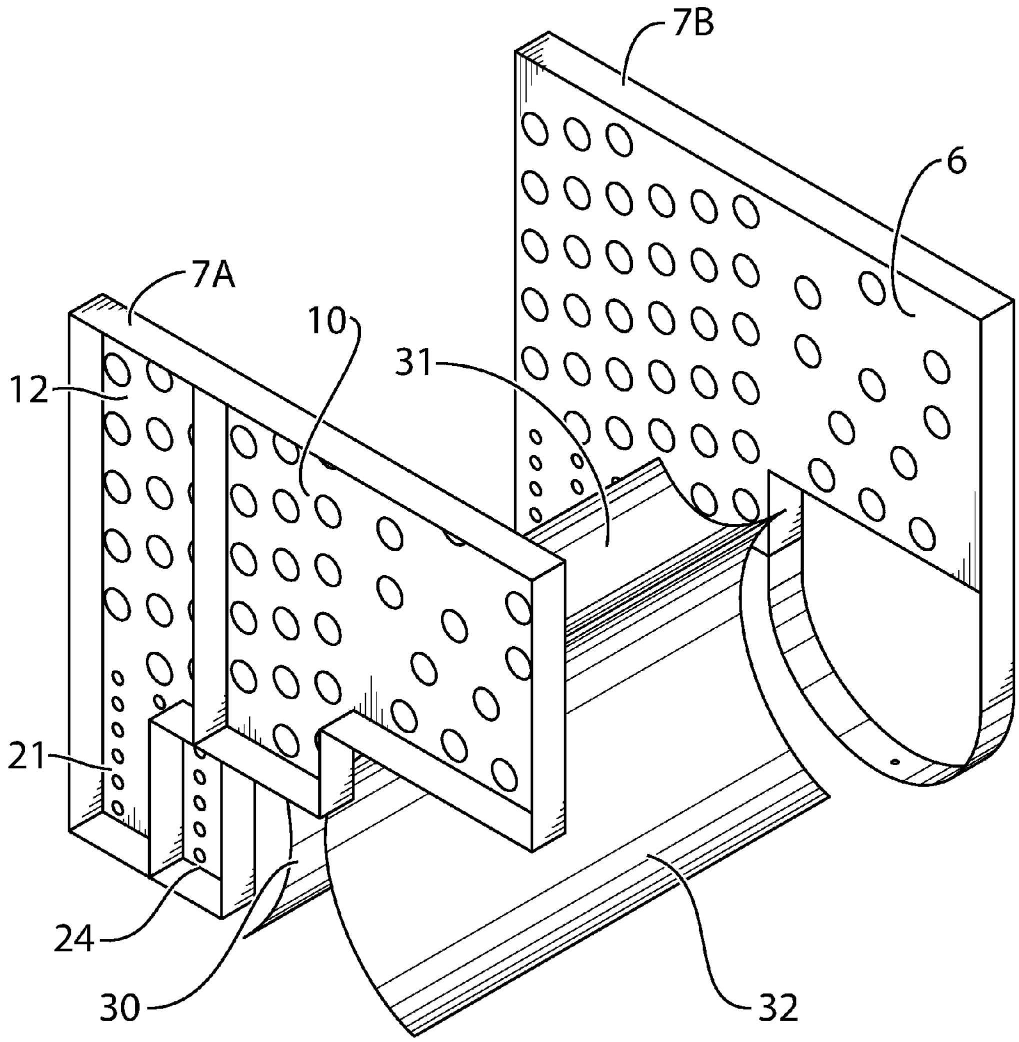


FIG. 2B

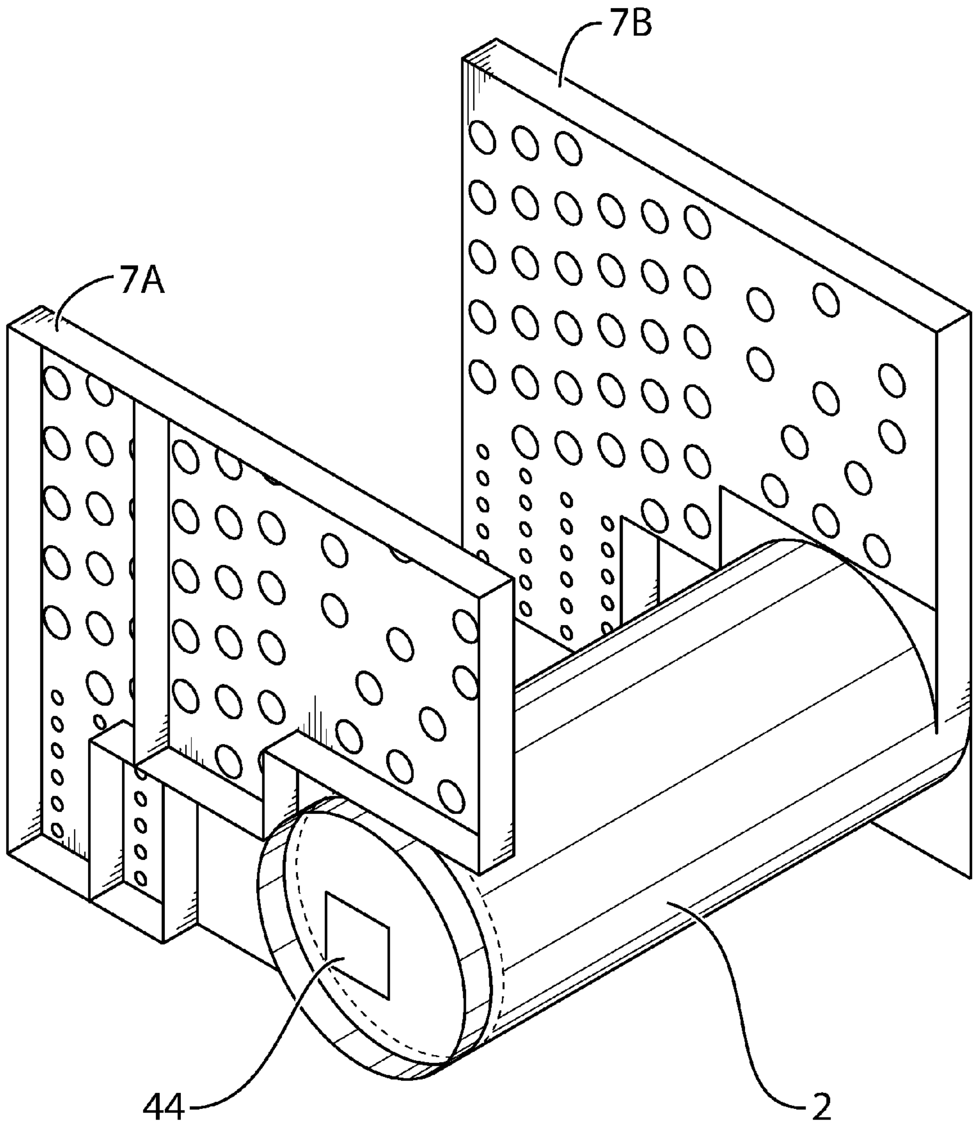


FIG. 2C

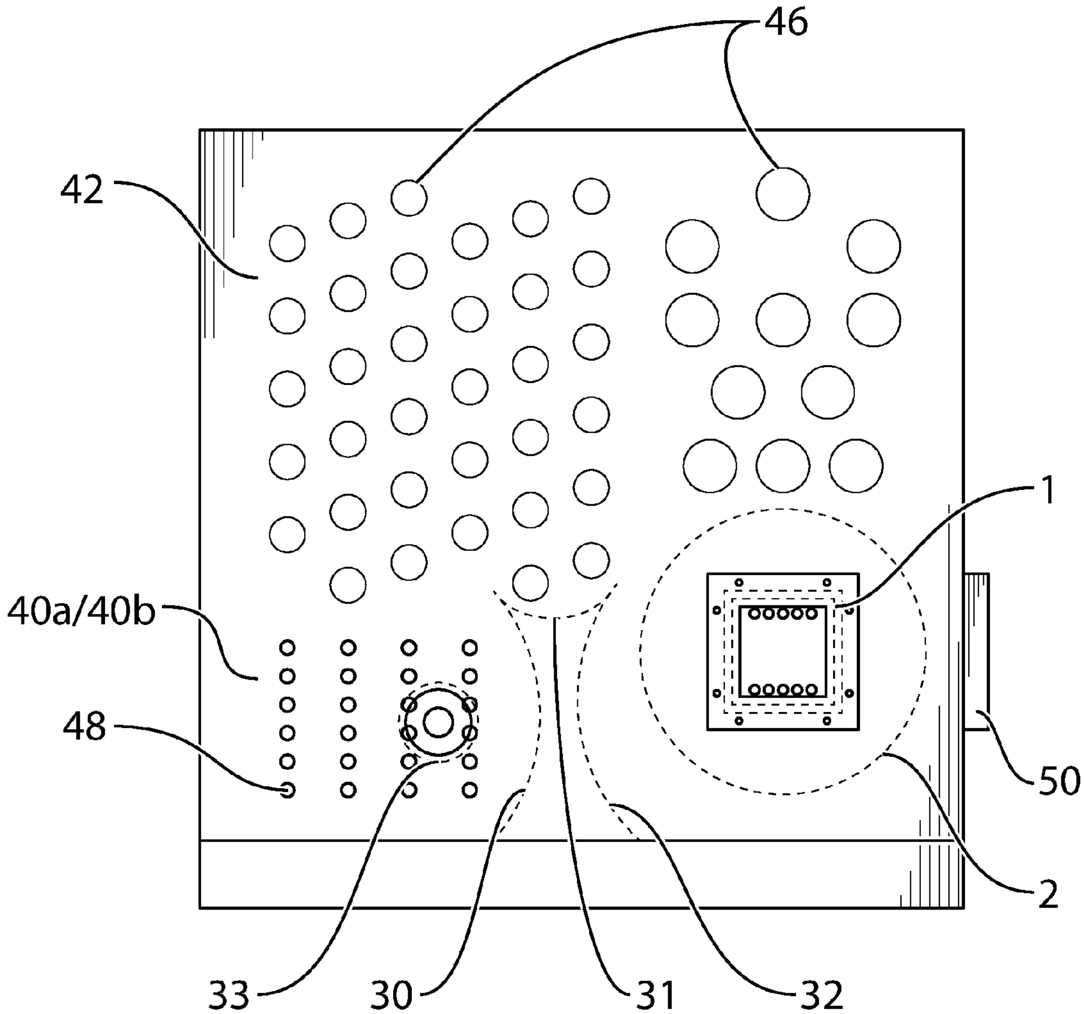


FIG. 3

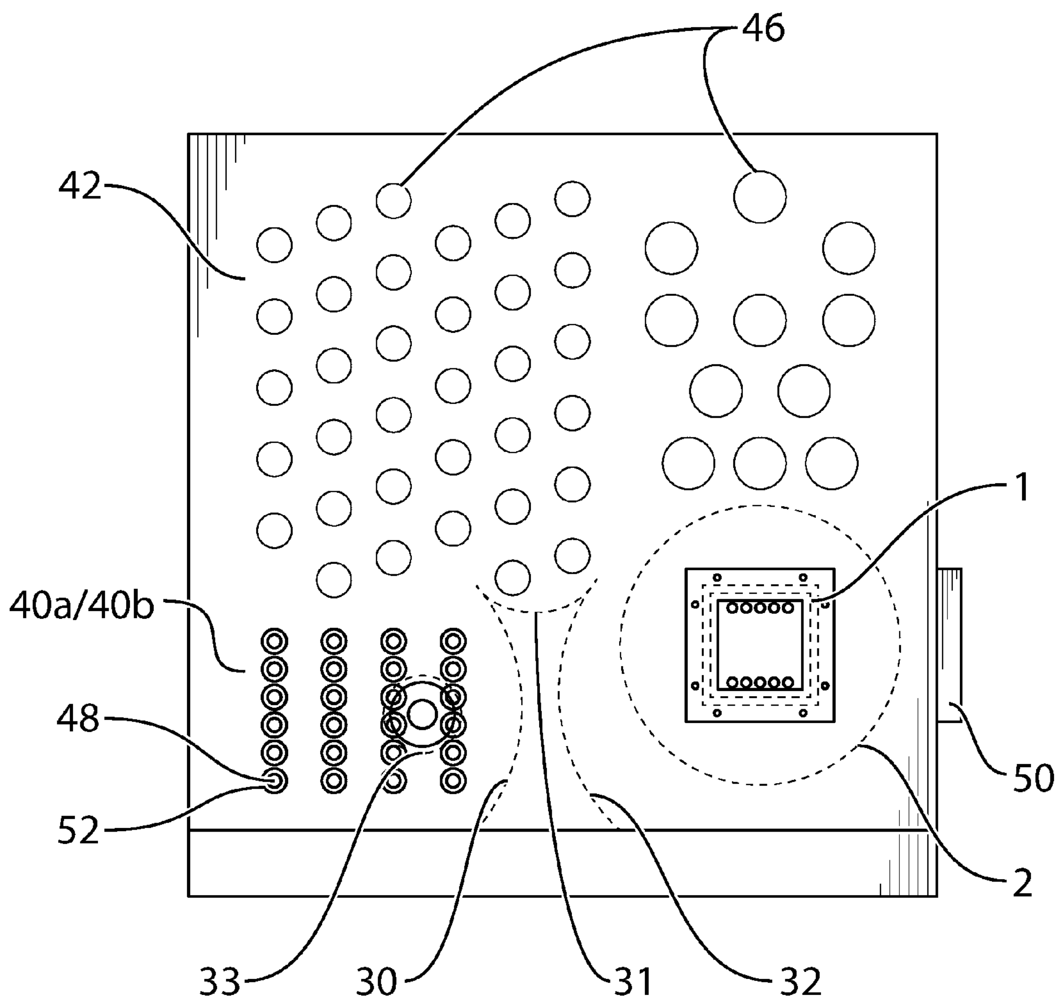


FIG. 4

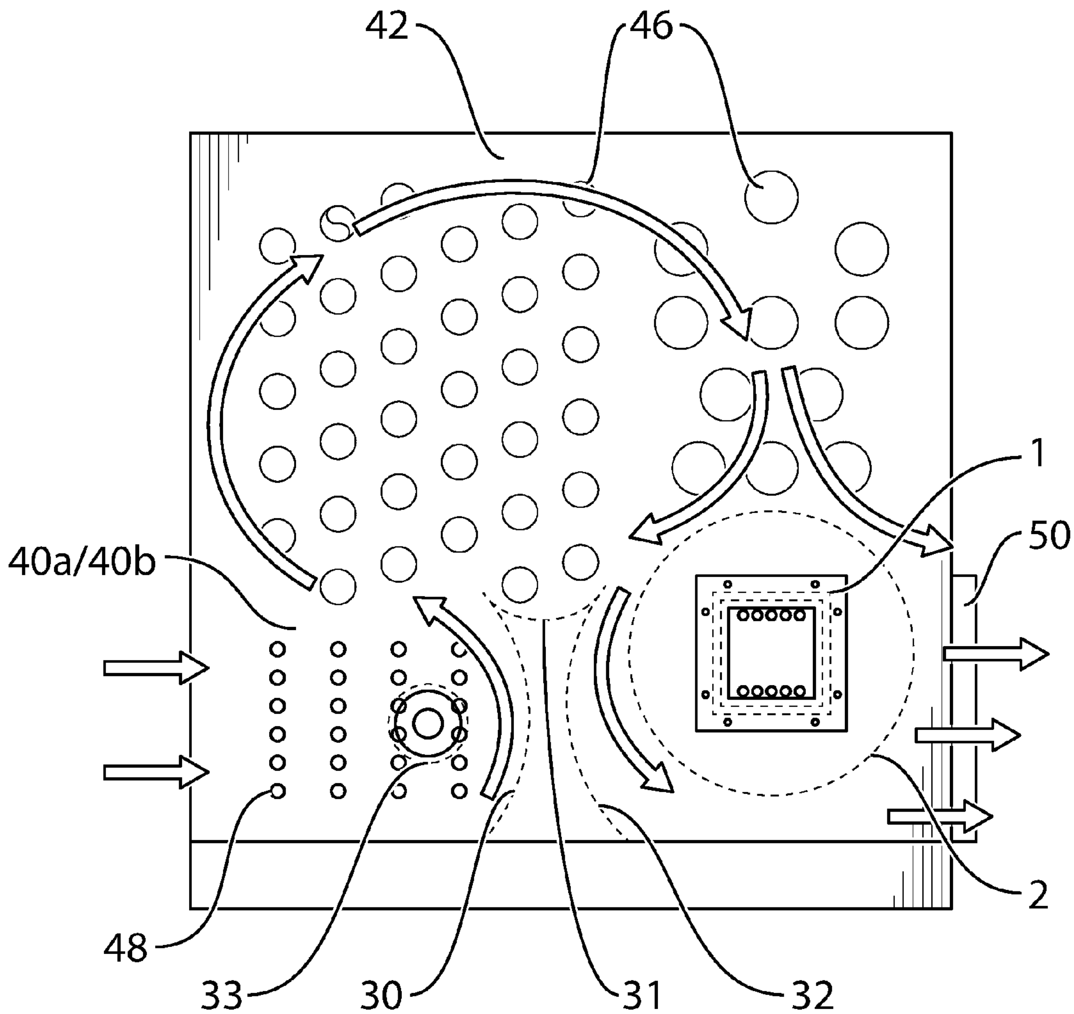


FIG. 5

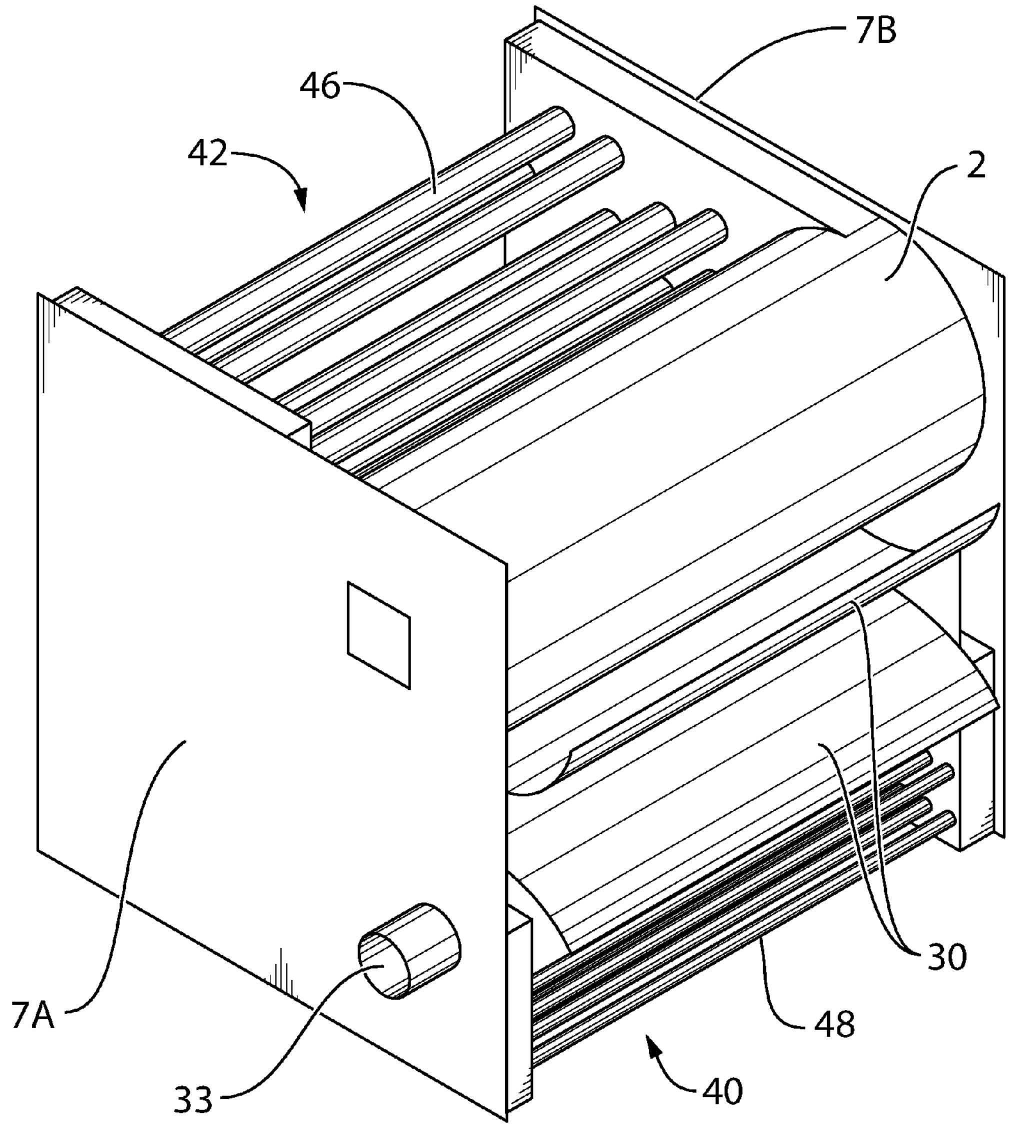


FIG. 6

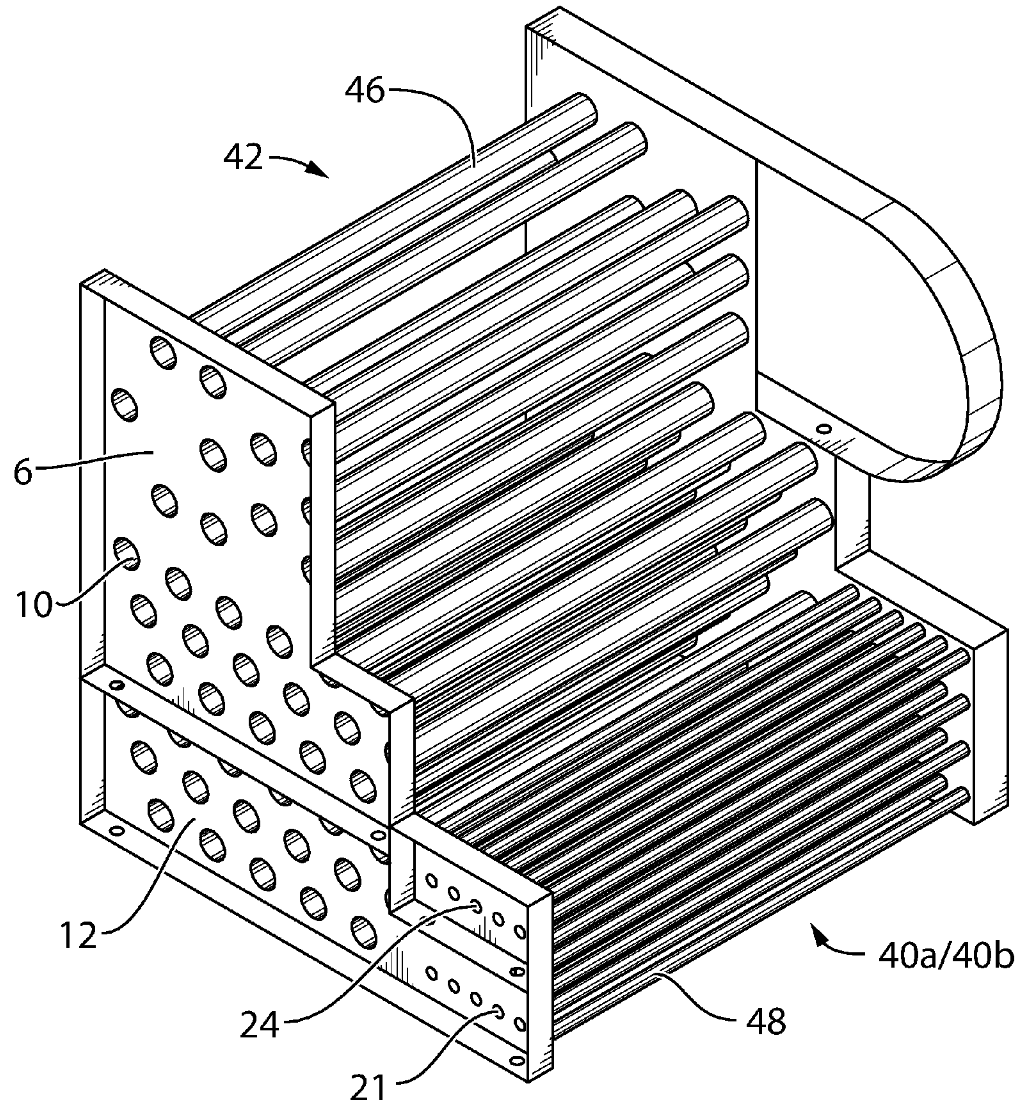


FIG. 7

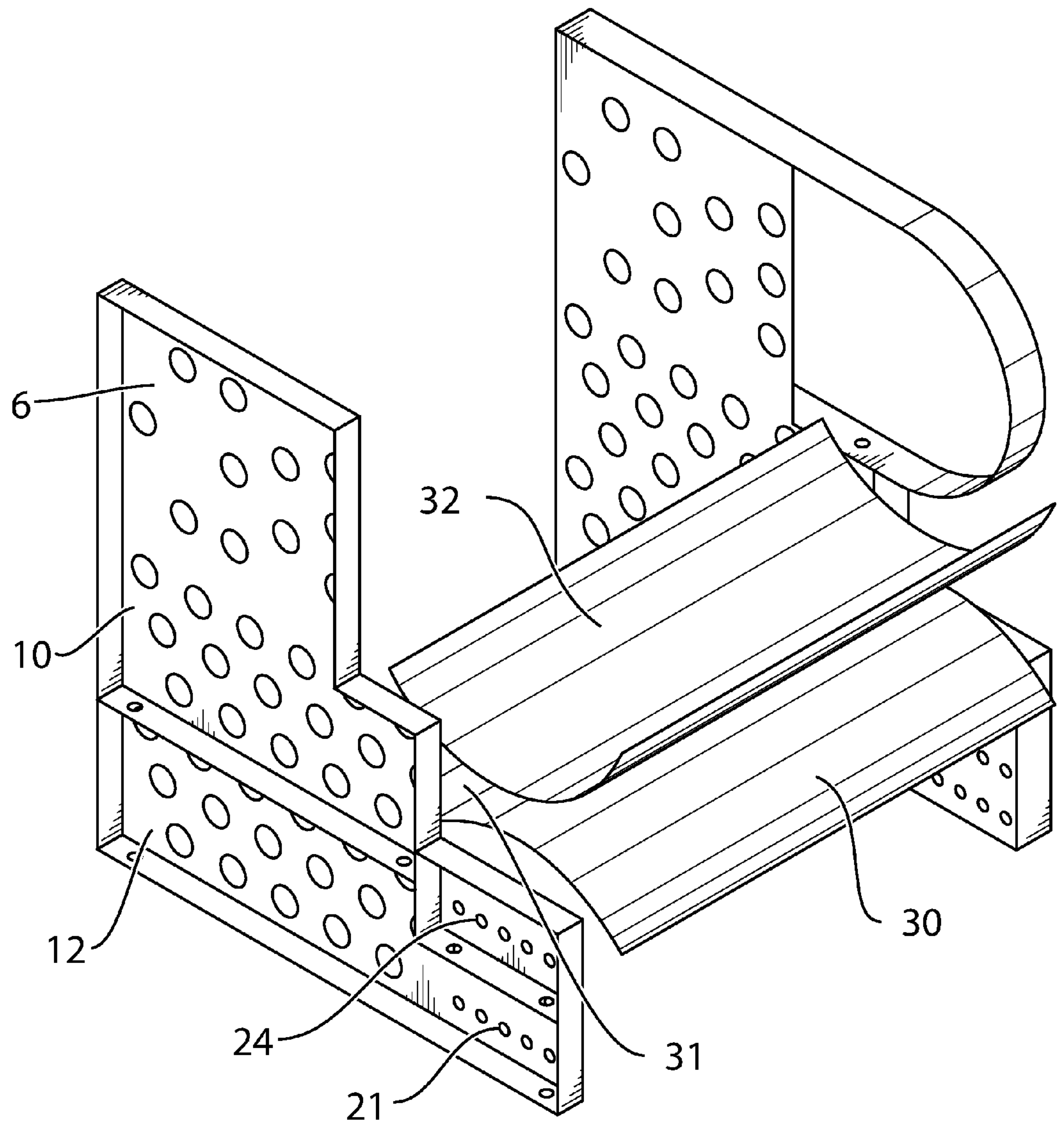


FIG. 8

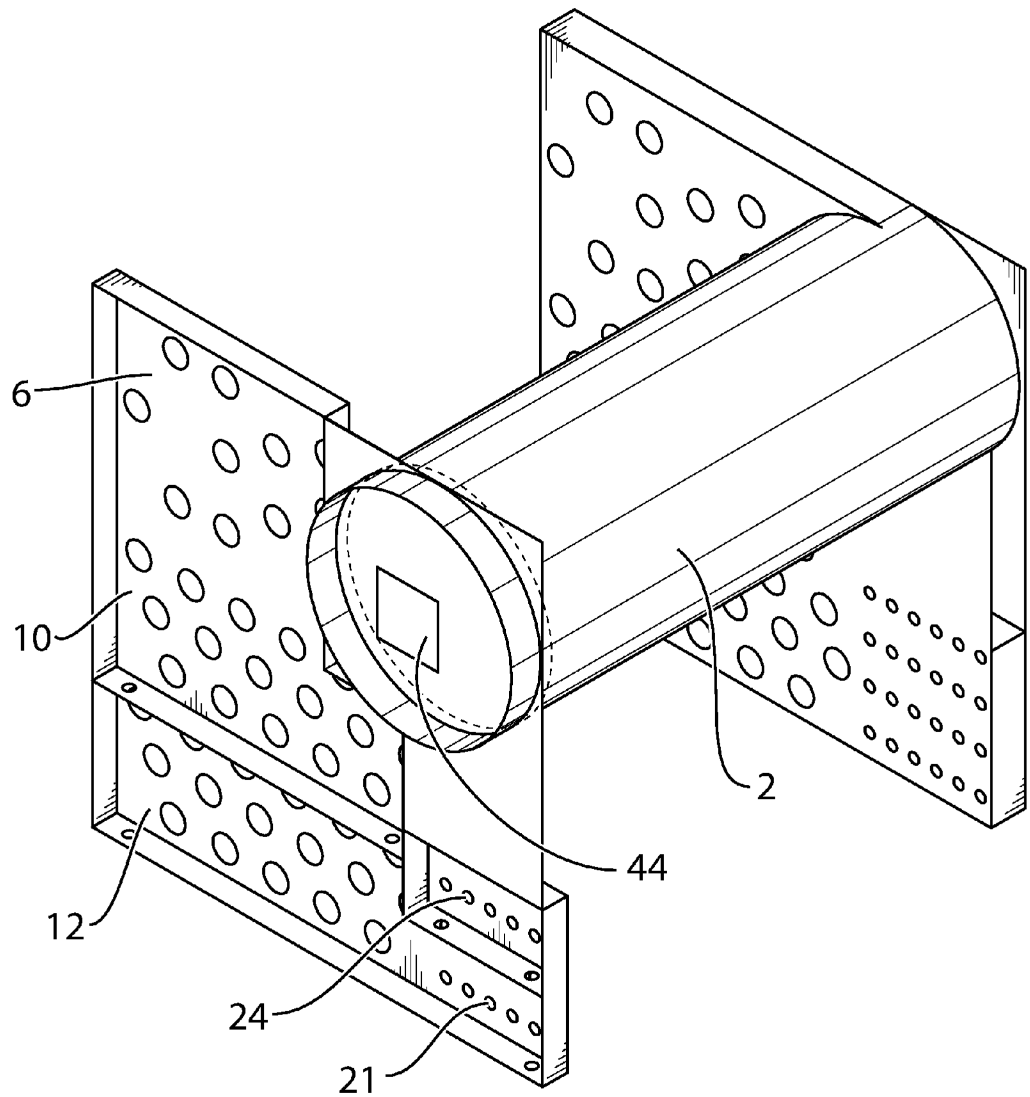


FIG. 9

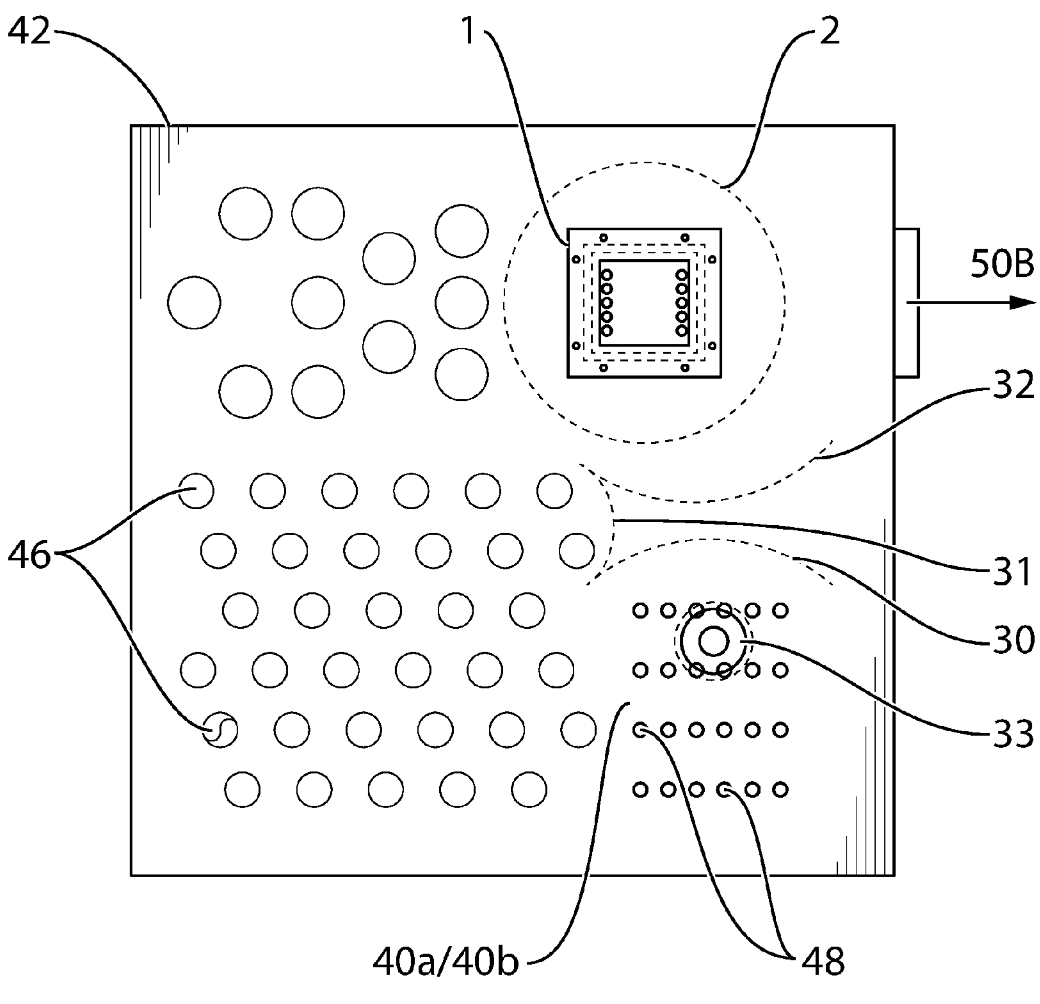


FIG. 10A

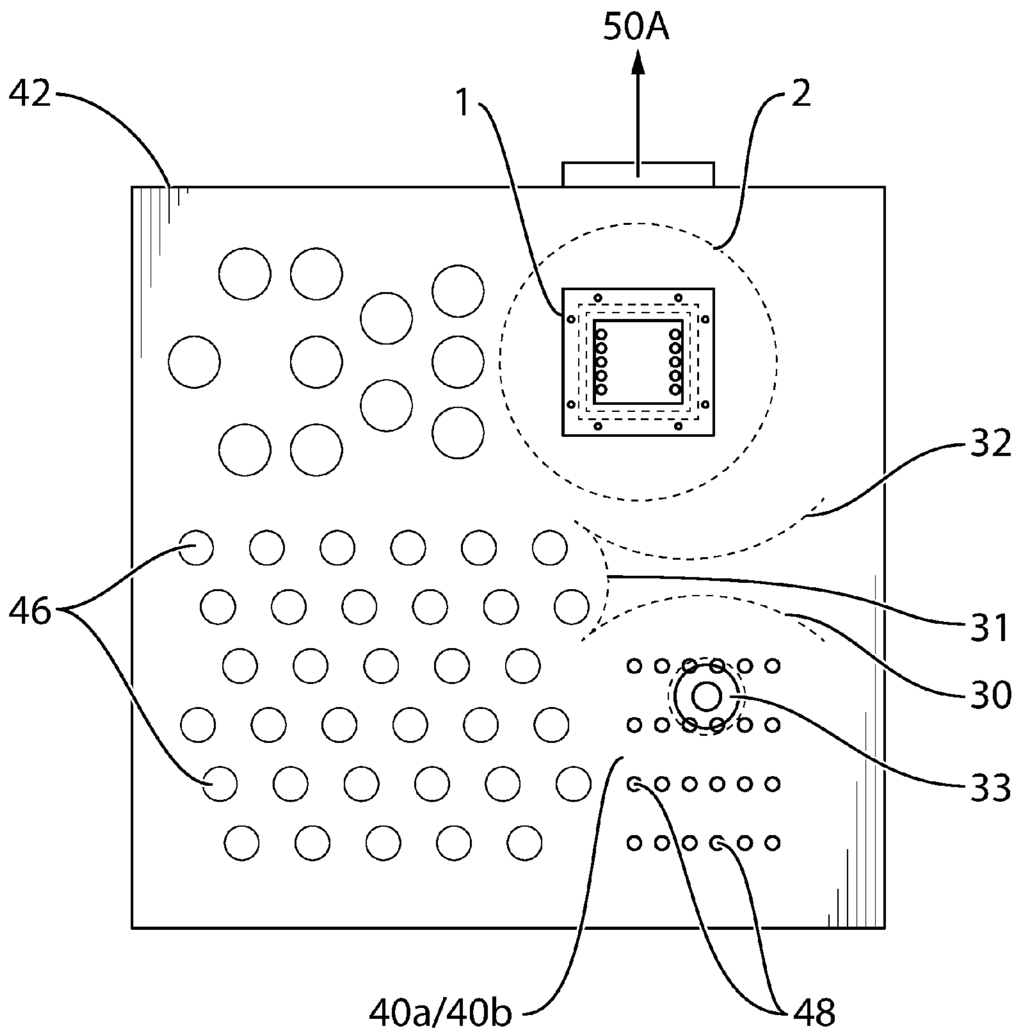


FIG. 10B

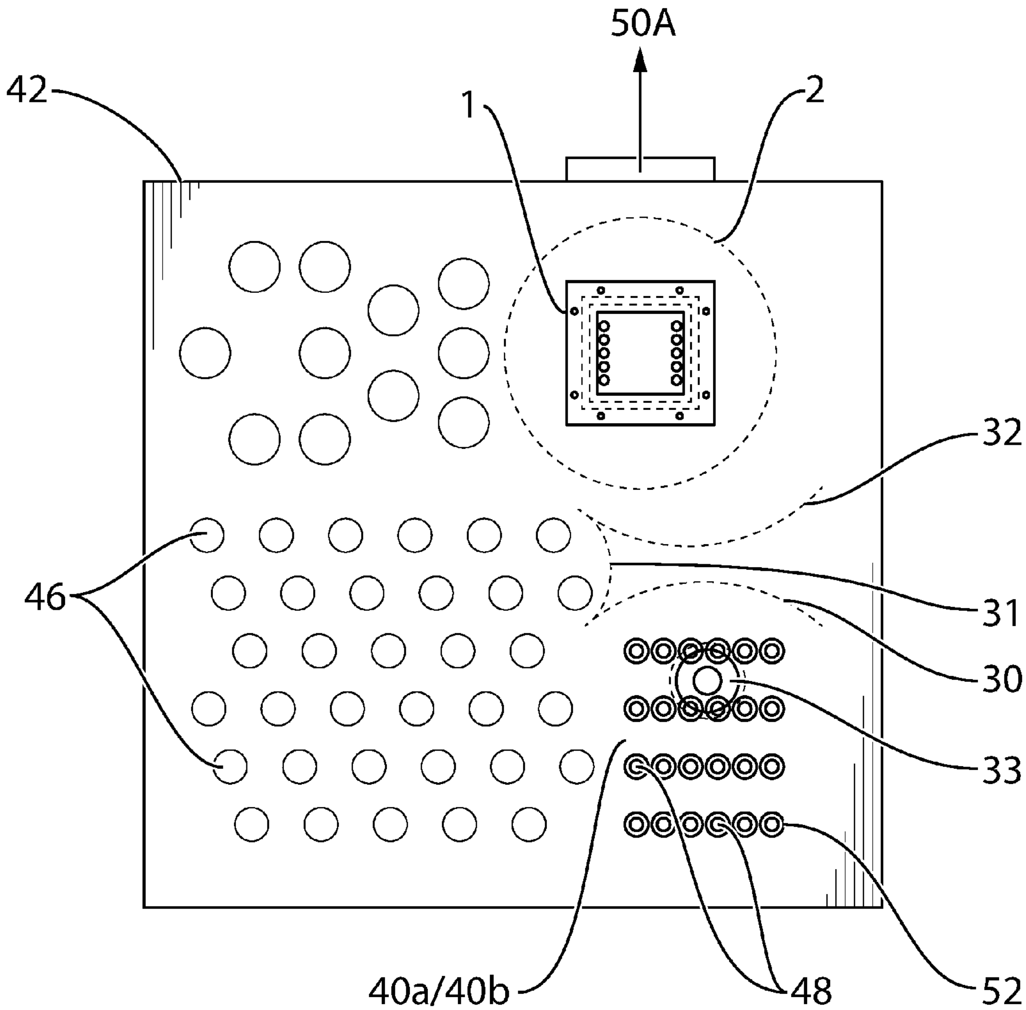


FIG. 11C

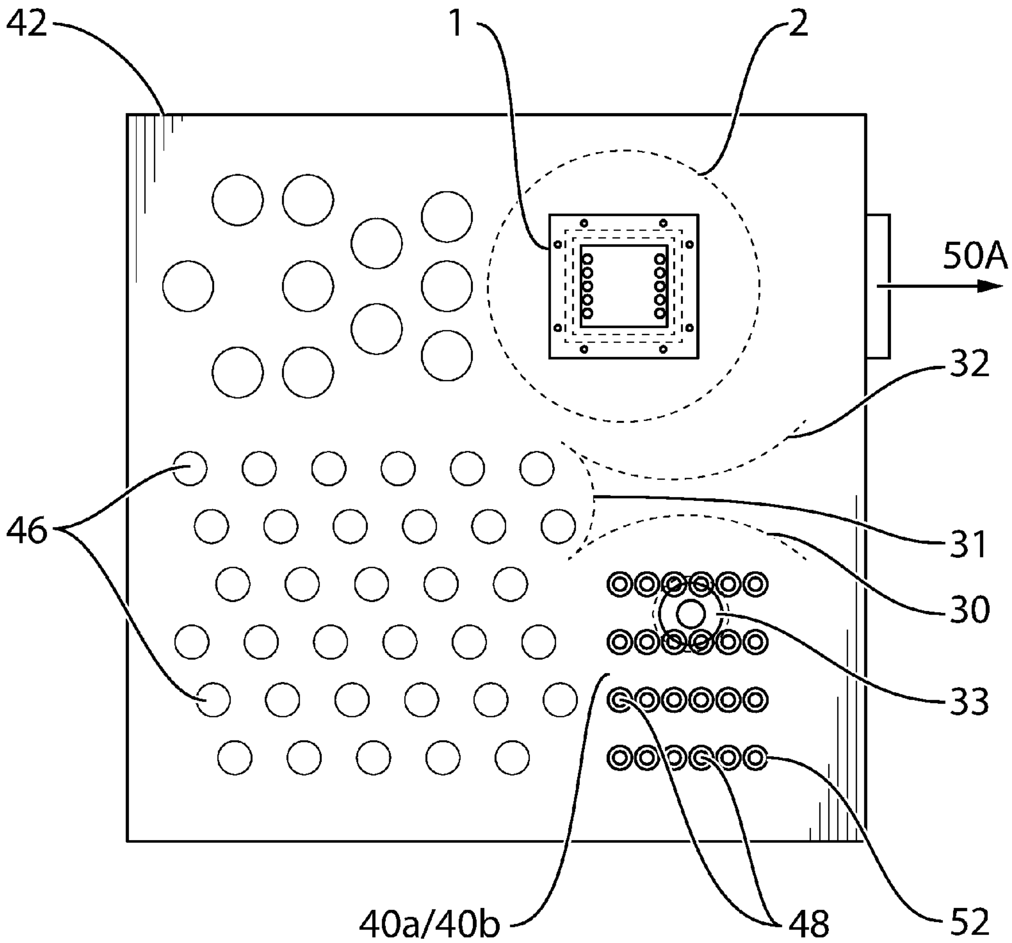


FIG. 10D

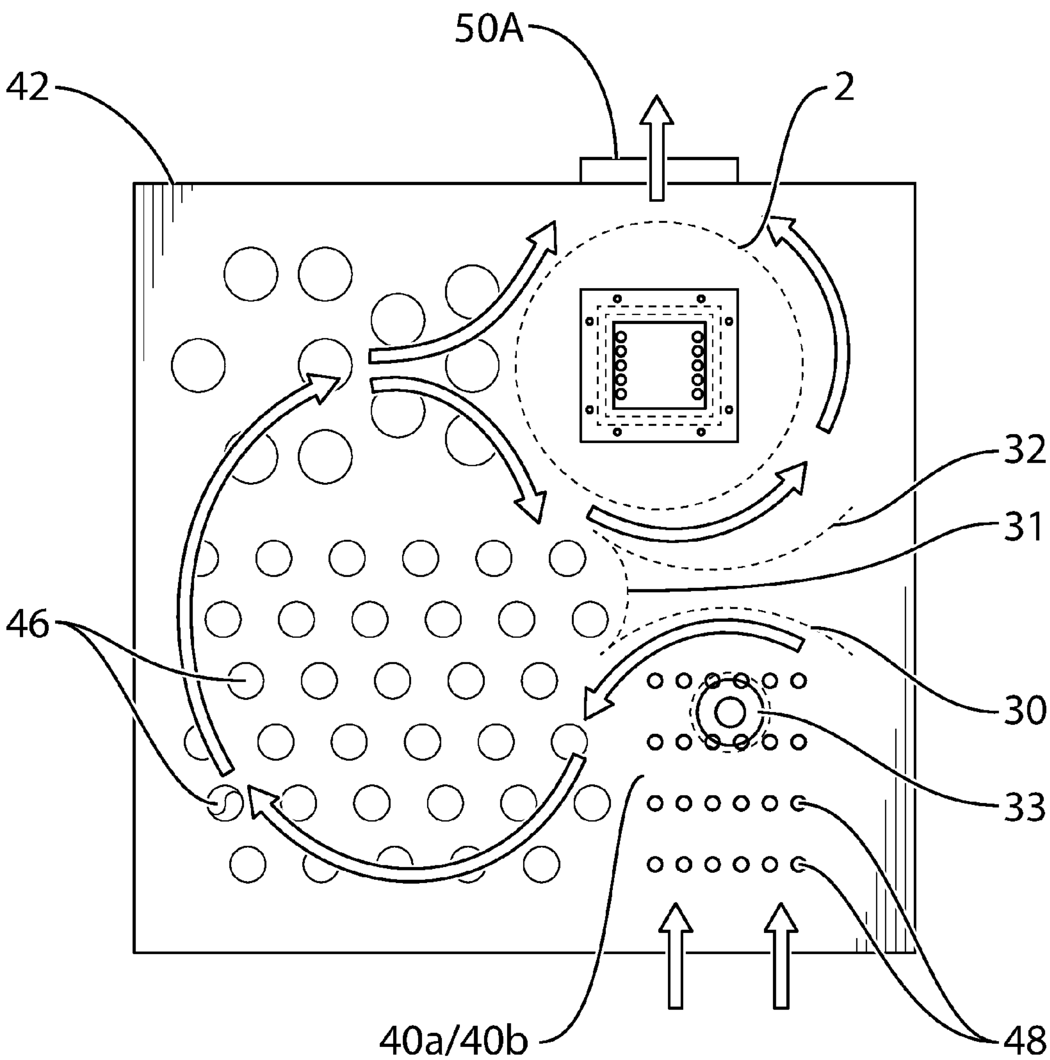


FIG. 11A

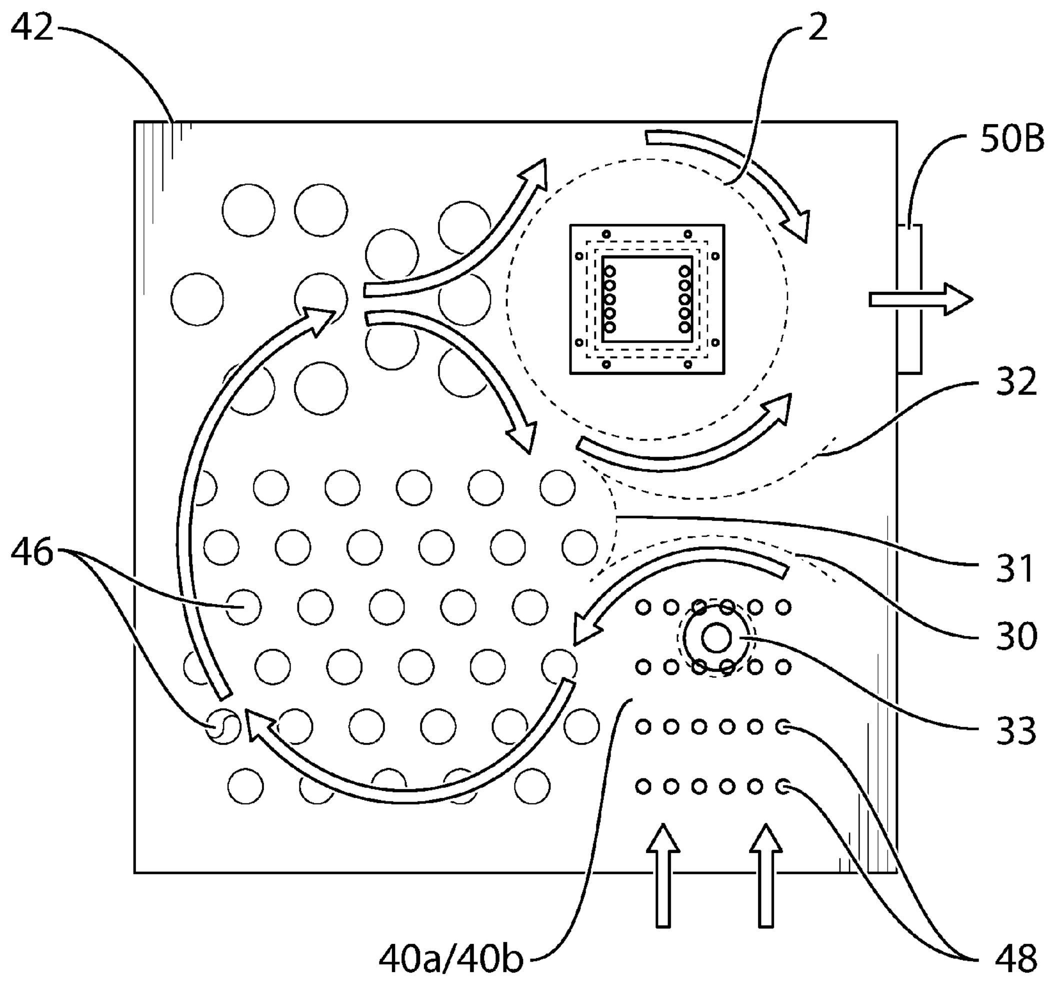


FIG. 11B

INDIRECT FIRED HEAT EXCHANGER

FIELD OF THE INVENTION

[0001] The present invention relates to an indirect fired heat exchanger.

BACKGROUND

[0002] Indirect fired heaters and furnaces are commonly used in heating residential, commercial and industrial spaces.

[0003] Unlike direct fired heaters, in indirect fired heat exchangers and furnaces, the burner is fired into a drum and tube type heat exchanger and the products of combustion do not come in contact with the process air within the work chamber. Process air or gas is forced by a combustion blower into the heat exchanger and travels through the heat exchanger drum and tubes and the air that passes over the heat exchanger is heated and then directed to its destination via externally attached duct work.

[0004] Government regulations surrounding efficiency of indirect fired heat exchangers has become increasingly stringent. Fuel costs and environmental considerations also lead to increased demand for high efficiency heat exchangers.

[0005] Attempts have been made in the past to improve heat exchanger efficiency, which is measured as the percentage of energy input by the heat exchanger's burner that is translated to energy output from the existing flue gas. The energy input from the fuel is typically measured by thousands of BTU's per hour (MBH).

[0006] In some cases the materials of construction have been varied to optimize heat transfer or to insulate from heat losses. In other cases, fins have been added to the tubes of the heat exchanger to increase heat transfer.

[0007] In other cases, configuration of the tubes of the furnace has been altered in an effort to improve efficiencies.

[0008] U.S. Pat. No. 5,322,050 and related U.S. Pat. No. 5,406,933 teach a fuel-fired condensing furnace having a number of modifications thereto. These include a smaller than typical outside diameter of the combustion tubes, specifically an outside diameter OD of from 1⅛" to 1½" and correlating the firing rate of the furnace to the flame tube size in a manner such that the firing rate per unit inner cross-sectional area of the flame tubes is within the range of from about 9,000 to 13,000 Btu/hr/in^2.

[0009] However there is still a need in the art to find means for improving heat exchanger efficiencies.

SUMMARY

[0010] An indirect fired heat exchanger is provided, comprising an arcuate airflow pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention will now be described in greater detail, with reference to the following drawings, in which:

[0012] FIG. **1** is a front perspective view of one embodiment of the indirect fired heat exchanger of the present invention;

[0013] FIG. **2**A-**2**C are further front perspective views of one embodiment of the indirect fired heat exchanger of the present invention;

[0014] FIG. **3** is a front cross sectional elevation view of one embodiment of the indirect fired heat exchanger of the present invention with finless radiator tubes;

[0015] FIG. **4** is a front cross sectional elevation view of one embodiment of the indirect fired heat exchanger of the present invention, with finned radiator tubes;

[0016] FIG. **5** is a front cross sectional elevation view of one embodiment of the indirect fired heat exchanger of the present invention showing the omega airflow pattern;

[0017] FIG. **6** is a front perspective view of another embodiment of the indirect fired heat exchanger of the present invention;

[0018] FIG. **7** is a front cross sectional perspective view of an alternate embodiment of the indirect fired heat exchanger of the present invention;

[0019] FIG. **8** is a further front perspective view of one embodiment of the containment plates and baffles of an alternate embodiment the indirect fired heat exchanger of the present invention;

[0020] FIG. **9** is a front perspective view of one embodiment of the containment plates and drum of an alternate embodiment the indirect fired heat exchanger of the present invention;

[0021] FIG. **10**A is a front cross sectional elevation view of an alternate embodiment of the indirect fired heat exchanger of the present invention with finless radiator tubes and a side discharge;

[0022] FIG. **10**B is a front cross sectional elevation view of an alternate embodiment of the indirect fired heat exchanger of the present invention, with finless radiator tubes and a top discharge;

[0023] FIG. **10**C is a front cross sectional elevation view of an alternate embodiment of the indirect fired heat exchanger of the present invention, with finned radiator tubes and a tope discharge;

[0024] FIG. **10**D is a front cross sectional elevation view of an alternate embodiment of the indirect fired heat exchanger of the present invention, with finned radiator tubes and a side discharge;

[0025] FIG. **11**A is a front cross sectional elevation view of an alternate embodiment of the indirect fired heat exchanger of the present invention showing the omega airflow pattern on a top discharge; and

[0026] FIG. **11**B is a front cross sectional elevation view of an alternate embodiment of the indirect fired heat exchanger of the present invention showing the omega airflow pattern on a side discharge.

DESCRIPTION OF THE INVENTION

[0027] The invention provides an indirect fired condensing heater having a novel heat exchanger. The present heat exchanger has shown high performance efficiencies of up to 95.7% when fins are present on the last one or more passes of the heat exchanger tubes.

[0028] With reference to FIGS. **1** to **10**, one embodiment of the present heat exchanger is illustrated. The present heat exchanger comprises a final pass section **40**, a heat exchanger assembly **42** and an inlet **44** from a burner to the heat exchanger.

[0029] A plurality of first heat exchanger tubes **46** are positioned in the heat exchanger assembly **42** and a plurality of final pass heat exchanger tubes **46** are positioned in the final pass section **40** before discharge of combustion products as flue gasses.

[0030] The arrangement of the heat exchanger containment plates **7**A/**7**B is illustrated in more detail in FIGS. **5** and **6**. These containment plates **7**A/**7**B divide the heat exchanger into a series of passes to direct combustion gases from the burner **1**, through the primary drum **2**, then a first pass **6** of heat exchanger tubes, a second pass **10** of heat exchanger tubes, a pass section **12** of heat exchanger tubes, a first pass **21** of final pass heat exchanger tubes and finally through a second pass **24** of final pass heat exchanger tubes, at which point the combustion gases are vented to a flue stack through the heat exchanger discharge vent **33**.

[0031] The present heat exchanger comprises a larger number of heat exchanger tubes and radiator tubes than typically seen in the art. Preferably, the number of tube passes in the heat exchanger assembly **42** is increased from that typically seen in known heat exchangers in the art. Further preferably the number of tube passes in the final pass section **40** is also increased from that typically seen in known heat exchangers in the art.

[0032] In a preferred embodiment, and as illustrated in FIGS. **3**A, **3**B and **4**, the present heat exchanger assembly **42** comprises a total of forty five first heat exchanger tubes **46**. More preferably a portion of the first heat exchanger tubes **46** are arranged in a semi-offset pattern, while another portion are arranged in a random stagger pattern. Most preferably, thirty-four first heat exchanger tubes **46** are set in a semi-offset pattern above the final pass section **40***a*/**40***b* and eleven first heat exchanger tubes **46** are set in a random stagger pattern **6** above the primary drum **2**. Most preferably, the first heat exchanger tubes **46** have a diameter of from 2.5" to 3.5" and are made of 409 stainless steel.

[0033] The present inventors have found that the combination of semi-offset and random stagger pattern, creating a three pass tube exchanger arrangement of the first heat exchanger tubes **46** allows for maximum heat transfer with minimal loss of airflow across the heat exchanger assembly section **42**.

[0034] In further a preferred embodiment, the present heat exchanger comprises twenty four final pass heat exchanger tubes **46**. More preferably the final pass heat exchanger tubes **46** are aligned in a horizontal in-line stack configuration. Most preferably, the final pass heat exchanger tubes **46** are 1" to 1.5" in diameter and are made of 409 stainless steel. The final pass heat exchanger tubes **46** may have external fins or they may be finless.

[0035] In a preferred embodiment, the final pass section **40** of the present heat exchanger is a two pass section illustrated as sections **40***a* and **40***b* in FIG. **2***a*.

[0036] The present inventors have found that the present size, number and arrangement of final pass heat exchanger tubes **46** provide minimal pressure drop from the process air supply fan. As well the present inventors have found that locating final pass section **40***a*/**40***b* proximal the inlet of air to be heated, as seen in FIG. **4**, and having final pass heat exchanger tubes **46** fabricated from more conductive 409 stainless steel, has shown increased efficiency of the heat exchanger. Heat exchanger efficiency was found to be in the order of 90% or more with no radiator fins. In a preferred embodiment of the present heat exchanger, fins **52** are added to the final pass heat exchanger tubes **46** of the two pass final pass section **40***a*/**40***b*, resulting in an efficiency increase to the order of 95% or more. Most preferably, the fins **52** run radially around the exterior diameter of the final pass heat exchanger tubes **46**. Further most preferably, the fins **52** are 0.5" in height and are arranged along the length of the final pass heat exchanger tubes **46** at intervals that accommodate airflow and prevent clogging, most preferably at intervals of six fins **52** per inch of length. Most preferably, the fins **52** are made of copper or aluminum.

[0037] Most preferably, the first heat exchanger tubes **46** have internal turbulators to cause turbulent flow through the first heat exchanger tubes **46**. Sizing of the final pass heat exchanger tubes **46** advantageously provides turbulent flow without the need for internal turbulators or similar devices.

[0038] A process air supply fan (not shown), which may or may not be provided as part of the heat exchanger of the present invention, supplies process air to be heated to a process air inlet on the heat exchanger. In a preferred embodiment as illustrated in FIG. **4**, supply air from the process air supply fan enters the heat exchanger at the final pass section **40***a*/**40***b* travels over the final pass heat exchanger tubes **46** and then over the first heat exchanger tubes **46** and exits the heat exchanger with final pass across primary drum **2** through a process airflow outlet in the form of discharge opening in the heat exchanger.

[0039] In a preferred embodiment, airflow through the heat exchanger follows an arcuate flow path. In a more preferred embodiment, the airflow pattern creates horseshoe pattern. In a most preferred embodiment air flows through the heat exchanger in an "omega" (Ω) shaped airflow, as illustrated by the curved arrows in FIG. **4**.

[0040] The present heat exchanger preferably comprises one or more baffles, and more preferably three interconnected baffles **30**, **31** and **32** that form a process airflow diversion within the heat exchanger. The baffles **30**, **31** and **32** direct airflow into the omega (Ω) flow pattern. The present inventors have found that this omega (Ω) flow pattern provides a significant increase in heat exchanger efficiency over traditional S-shaped flow patterns commonly seen in the art.

[0041] As heat is removed from combustion gasses traveling through the primary drum **2**, first heat exchanger tubes **46** and radiator tubes **42**, moisture in the combustion gas condenses to form condensate. Combustion gas condensate is typically acidic and can cause internal fouling and corrosion of the heat exchanger tubes and primary drum if not properly drained and discharged. The acidic condensate is not deemed acceptable by plumbing code to be disposed of directly into a drainage system. A condensate neutralization system may be used in conjunction with the present invention for condensate neutralization and acceptably safe disposal. Preferably, the heat exchanger tubes and radiator tubes as well of the present heat exchanger are oriented to optimize gravity drainage of condensate to the condensate neutralization system.

[0042] While the above mentioned invention is described for typical horizontal air flow delivery to the building space, alternate approaches to air flow delivery are also possible and encompassed by the scope of the current invention.

[0043] For example, the heat exchanger can be designed for vertical air delivery to a building space to be heated. Such configuration is illustrated in FIGS. **6** to **12**; and can generally be described as the horizontal air flow delivery configuration, when viewed from its front end as seen in FIGS. **3**A-B and **4**, rotated clockwise by 90°. In this configuration, the final pass section **40***a*/**40***b* is located below the drum **2** and the drum **2** is located in an upper corner of the heat exchanger, above the final pass section **40***a*/**40***b*. The first heat exchanger tubes **46** now form a heat exchanger assembly **42** that approximately spans a vertical half section of the heat exchanger. The sizing, spacing, configuration and materials of final pass heat exchanger tubes **46** and heat exchanger tubes **42** can be the same as those described above with respect to a horizontal air delivery system.

[0044] In the present alternate embodiment, a process air supply fan (not shown), which may or may not be provided as part of the heat exchanger of the present invention, supplies process air to a process air inlet on a shell side of the heat exchanger. Preferably the process air enters the heat exchanger at the final pass section **40***a*/**40***b* travels over the final pass heat exchanger tubes **46** and then over the first heat exchanger tubes **46** and exits the heat exchanger with final pass across primary drum **2** through a process air outlet in the form of a discharge opening **50** in the heat exchanger.

[0045] With reference to FIGS. **11**A-D, the heat exchanger of this alternate embodiment is arranged to discharge heated air from a process air outlet in the form of a heated air discharge **50***a*/**50***b* that is substantially vertically displaced from the air inlet to the heat exchanger, and more preferably the heated air discharge **50** is higher than the air inlet to the heat exchanger. In a further preferred embodiment, the heated air discharge can be any one of a horizontal top flow discharge **50***a* or an upper side discharge **50***b*.

[0046] Airflow through the heat exchanger in this alternate embodiment also follows an arcuate flow path, more preferably the airflow pattern creates horseshoe pattern and most preferably air flows through the heat exchanger in an "omega" (Ω) shaped airflow, as illustrated by the curved arrows in FIGS. **12**A and **12**B.

[0047] The baffles (**30**, **31**, **32**) of the heat exchanger of this alternate embodiment the invention still form a process airflow diversion within the heat exchanger. The baffles **30**, **31** and **32** direct airflow into the omega (Ω) flow pattern, however, in the alternate embodiment the omega pattern is shifted by 90°. The omega (Ω) flow pattern has shown to provide significant increases in heat exchanger efficiency regardless of orientation.

[0048] The alternate embodiment illustrated in FIGS. **6** to **12** provides an advantageously reduced foot print over the horizontal airflow design, which in turn allows for favorable installation in space restricted areas such as mechanical rooms or outdoor vertical applications. Efficiency of the alternate embodiment of the heat exchanger illustrated in FIGS. **6**-**12** was also found to be 90% or more, in models with finless final pass heat exchanger tubes **46**. Preferably, fins **52** are included on final pass heat exchanger tubes **46** of the alternate embodiment, which increases heat exchanger efficiency to 95% or more.

[0049] In the foregoing specification, the invention has been described with a specific embodiment thereof; however, it will be evident that various modifications and changes may be made thereto without departing from the broader scope of the invention.

1. A heat exchanger for use in an indirect fired heater, said heat exchanger comprising an arcuate process airflow pattern.

2. The heat exchanger of claim **1**, wherein the arcuate process airflow pattern is a horseshoe shaped airflow pattern.

3. The heat exchanger of claim **1**, wherein the arcuate process airflow pattern is an omega-shaped pattern.

4. The heat exchanger of claim **1**, wherein the process airflow pattern is directed by one or more baffles arranged within the heat exchanger.

5. The heat exchanger of claim **4**, wherein the process airflow pattern is directed by three connected baffles forming an airflow diversion within the heat exchanger.

6. The heat exchanger of claim **1**, further comprising a final pass section situated adjacent to a process airflow inlet such that process airflow from a process airflow inlet travels firstly over the final pass section.

7. The heat exchanger of claim **6**, wherein the final pass section comprises multiple final pass heat exchanger tubes arranged in a horizontal in-line stack configuration.

8. The heat exchanger of claim **7** wherein the final pass section is a two pass section.

9. The heat exchanger of claim **7**, wherein the multiple final pass heat exchanger tubes are finless.

10. The heat exchanger of claim **7**, wherein the multiple final pass heat exchanger tubes comprise external fins.

11. The heat exchanger of claim **10**, wherein the fins are 0.5" wide and are spaced at an interval of 6 fins per inch along the length of the final pass heat exchangers tubes.

12. The heat exchanger of claim **7**, further comprising a three-pass heat exchanger section between the final pass heat exchanger section and a primary drum, wherein the primary drum is situated adjacent a process airflow outlet such that process airflow travels lastly over the primary drum.

13. The heat exchanger of claim **12**, wherein the heat exchanger section comprises multiple first heat exchanger tubes, said first heat exchanger tubes being arranged in one more patterns selected from the group consisting of a semi-offset pattern and a random stagger pattern.

14. The heat exchanger of claim **13**, wherein a first portion of the first heat exchanger tubes are arranged in a semi-offset pattern and a second portion of the first heat exchanger tubes are arranged in a random stagger pattern.

15. The heat exchanger of claim **13**, wherein the first heat exchanger tubes and final pass heat exchanger tubes are oriented to promote gravity drainage of condensate from the first and final heat exchanger tubes.

16. The heat exchanger of claim **12**, wherein the process airflow inlet and the process airflow outlet are substantially equidistant from a base of the heat exchanger.

17. The heat exchanger of claim **12**, wherein the distance from a base of the heat exchanger to the process airflow outlet is greater than the distance from the base of the heat exchanger to the process airflow inlet.

* * * * *